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EFFECT OF SPROUTED GREEN BUCKWHEAT ON ORGANOLEPTIC PROPERTIES AND MICROSTRUCTURE OF MEAT CUTLETS

Abstract: This study investigates the effect of sprouted green buckwheat (SGB) on the quality attributes of meat-based semi-finished products (cutlets). The primary aim was to evaluate the feasibility of incorporating SGB into traditional formulations to enhance sensory and structural characteristics. Meat blends were prepared by replacing horse and poultry meat with varying proportions (5%, 10%, 15%, 20%) of SGB. Organoleptic properties, including color, taste, consistency, flavor, and moisture, were assessed using a 5-point sensory scale. Microstructural analysis was also performed to observe distribution and integration of plant materials in the meat matrix. Results demonstrated that substitution up to 15% improved the texture and juiciness of cutlets, while 20% substitution negatively affected sensory quality. Microscopic images revealed enhanced structural uniformity with SGB inclusion. The findings support the potential of using sprouted green buckwheat as a functional plant-based ingredient to improve texture and consumer acceptability of meat cutlets without compromising quality. This study contributes to the development of low-calorie, nutritious semi-finished products with a balanced composition and functional properties.

Key words: horse meat, poultry meat, green buckwheat, mixed meat, meat and vegetable patties, quality food.

Introduction

Semi-finished meat products continue to be in consistently high demand, especially products enriched with functional ingredients and plant components such as vitamins, minerals, antioxidants and other useful substances. In order to ensure the necessary structural and plastic properties of minced meat, flour is used in the formulation of chopped semi-finished products as a binding component. Replacing some of the meat raw materials, such as horse meat, with sprouted green

buckwheat and flour from it can help enrich the product with nutrients that are not typical for traditional meat raw materials [1].

In this work, the organoleptic and physico-chemical quality indicators of combined semi-finished meat products were studied, the formulation of which included sprouted green buckwheat and flour from it. Generally accepted methods of organoleptic and physico-chemical analysis were used for the research. The results showed that replacing 15% of the meat with sprouted green buckwheat improves the juiciness, softness and uniformity of the product. However, an increase in the content of sprouted green buckwheat to 20% had a negative impact on the taste, smell and color of semi-finished products, which confirms the need for a careful approach when changing the recipe proportions. In modern society, there is a growing consumer interest in semi-finished products with a high degree of readiness, which is associated with the need for convenient and quickly prepared products. Along with this, the popularity of products containing non-traditional ingredients with a unique vitamin and mineral composition and high nutritional value is increasing. Products with the addition of amaranth, chickpeas, pumpkin flour, flax and chia seeds, as well as various berries and fruits are increasingly found on store shelves [2, 3]. This phenomenon also applies to meat products. In particular, semi-finished products are the most suitable group of meat products for the introduction of innovative ingredients, as they are the easiest to integrate new components that can simultaneously have a positive effect on technological properties and improve the nutritional value of the product [4].

When developing recipes for semi-finished meat products, one of the key steps is the correct choice of the main ingredients that can effectively bind the components of the cutlet mass together. For this purpose, herbal supplements with a high content of proteins, dietary fiber and other useful substances are often used, among which flour occupies a special place. The introduction of various types of flour into the formulation of meat products not only helps to improve the consistency of meat mass, but also allows you to enrich the product with important nutrients such as vegetable protein, fiber, vitamins and minerals. In addition, the use of flour gives the product specific organoleptic characteristics that can significantly affect the taste, texture and appearance of the finished product. Buckwheat, corn, oatmeal, flaxseed flour and other types of vegetable flour are valuable sources of vegetable protein, which supports the healthy functioning of the body, as well as fiber, which contributes to the normalization of the digestive system. In addition, each of these types of flour has its own unique complex of vitamins and minerals, such as B vitamins, magnesium, iron, and potassium, which makes them an important part of the diet. The use of such additives not only improves the nutritional value of meat products, but also makes it possible to create more diverse and balanced products that meet the needs of consumers for a healthy and delicious diet [5].

Recently, unprocessed buckwheat groats have become the most popular, which differs from traditional processed ones not only in its pale green hue, but also in the presence of natural biologically active substances [6]. Green buckwheat and flour obtained from such cereals are a valuable source of vitamins and minerals necessary for the normal functioning of the body, while it is absolutely gluten-free and is a unique vegetable source of protein [7, 10]. This flour contains about 15% protein, 82% carbohydrates, most of which are complex sugars. Green buckwheat proteins have high biological value and are optimally balanced in amino acid composition, which distinguishes them from proteins of other cereals. In addition, buckwheat proteins are characterized by good digestibility, which makes buckwheat flour products especially valuable for dietary nutrition. The fat content in buckwheat flour is low – less than 4%, and the fiber and ash substances in the flour are isolated from the main organic compounds. Buckwheat flour is also a source of carbohydrates, essential amino acids, vitamins and minerals such as magnesium, zinc, iron, potassium, rutin, as well as natural antioxidants and B vitamins and vitamin E [8, 9]. The dietary fibers of buckwheat flour include pectin, lignin, cellulose and hemicellulose, which have beneficial cleansing and healing effects on the human body.

In addition, the functional and technological properties of buckwheat flour, such as its ability to bind water and retain fat, make it especially valuable in the food industry. Studies by Sturza et al. (2020) [8] have shown that the ability of buckwheat flour to retain moisture exceeds that of wheat flour, and its fat-retaining properties are comparable to those of wheat flour. These qualities make buckwheat flour an excellent ingredient for creating products with improved textural and nutritional characteristics.

Materials and methods

Materials

A total of 40 kilograms of boneless horse rump steaks (*Musculus semimembranosus*) (moisture 75%, protein 21%, fat 2.2%, ash 1.4%) from female Jabe horses (aged 24-28 months and fattened for six months), 10 kg of horse fat from the same carcasses, and 8 kg of chicken thighs (aged four months, moisture 72.5%, protein 23.2%, fat 3.2%, ash 1.15%) were sourced from a commercial market in Semey, Kazakhstan, within one hour of slaughter. After collection, the meat cuts were carefully trimmed of visible fat and connective tissue. The samples were then vacuum-sealed and stored at -20°C until further use. Fresh onion (*Allium cepa*), cabbage (*Brassica oleracea* var. capitata), salt, and green buckwheat (*Fagopyrum esculentum*) grains were bought from a local market, cleaned, washed, and separately packed in polyethylene bags, then stored at 4°C in a refrigerator until use. All reagents used in the study were of analytical grade unless stated otherwise. The experiment was conducted in the laboratories of the Food Production and Biotechnology Department at Shakarim University, Semey, Kazakhstan.

Preparation of Germinated Green Buckwheat (GGB) and Its Flour

Commercial green buckwheat (*Fagopyrum esculentum*) was obtained from a local market in Semey, Kazakhstan, and used for the study. The germination process involved cleaning the grains to remove impurities, washing them, and soaking them in water at $32-33^{\circ}\text{C}$ for 20 min. The soaked grains were then germinated on water-soaked urethane foam at 23°C for 24 h in the dark, rinsing them thoroughly every 3 h and, if necessary, re-wetting the foam. After germination, the buckwheat grains were carefully removed and dried at 50°C for 24 h. The dried grains were finely ground using a laboratory mill and sieved through a <2 mm (10 mesh) sieve. The resulting germinated green buckwheat flour is white with a slight greenish tint and has a very fine texture. The flour was vacuum-sealed in PE/nylon film using a DZ-260PD vacuum packaging machine (Russia) and stored in a refrigerator at 4°C until required. The non-germinated buckwheat grains, used as a control, were dried at 50°C for 24 h, milled, and stored in a vacuum pack at 4°C . The antioxidant activity, total phenolic content, proximate composition, and pH of both germinated and non-germinated buckwheat flour were analyzed, with each test performed in triplicate. A flowchart of the buckwheat processing procedure is shown in Figure 1. The germination process lasted for seven days.

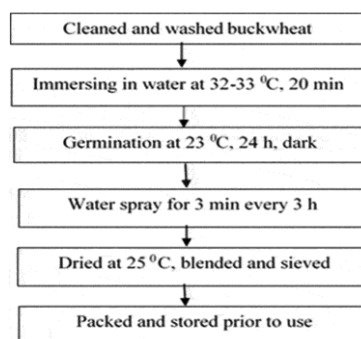


Figure 1 – The technological scheme of buckwheat processing

Antioxidant activity and TPC analysis of the flour

DPPH (2,2-diphenyl-1-picrylhydrazyl) is commonly used to evaluate antioxidant activity, as reported by the authors [5]. In the experiment, 10 mL of 80% CH_3OH was combined with 1 g of germinated green buckwheat flour (GGBF), shaken for 30 min at 25°C , and then centrifuged at 2000 rpm for 15 min. After centrifugation, 100 μL of the supernatant was added to 3.9 mL of DPPH (0.0025% w/v). The mixture was kept at 25°C for 1 h. Absorbance was measured at 517 nm using a UV-1800 Spectrophotometer (Shimadzu UV-1800, 115 VAC, Shimadzu, Japan) against methanol.

The TPC of the flour was determined using the method described by Beitâne et al. [9], with minor adjustments. In brief, 10 mL of CH_3OH was combined with 1 g of flour, stirred at 300 rpm for 1 h, and then filtered. To a 10 mL tube, 0.5 mL of the extract, 0.5 mL of Folin-Cochlea reagent, and 7 mL of distilled water were added and incubated at 25°C for 8 min. Afterward, 1.5 mL of 2% Na_2CO_3 was added, and the mixture was diluted to 10 mL with distilled water. The mixtures were shaken thoroughly and left to stand in the dark at 25°C for 2 h. Absorbance readings were taken at 765 nm using a UV/Vis spectrophotometer with 1 cm quartz cuvettes. The results were expressed as a mg of gallic acid equivalent (GAE) per 100 g of flour.

Cutlet formulation and production

The formulation of the patties was developed in the Department of Technology of Food Production and Biotechnology of the Shakarim University, Semey, Kazakhstan. The formulations of the patties with different additions of GGBF are given in Table 1. The patties were made with a mixture of horsemeat (highest grade and grade I) and poultry meat without any connective or adipose tissue. The formulation process began by cutting horsemeat, horse fat, and chicken meat into small cubes, which were then scalded in boiling water for five minutes using sealed plastic bags. Following this, the scalded horsemeat, chicken thigh meat, horse fat, sprouted green buckwheat grains, cabbage, and onion were minced using a Moulinex HV6 – ME511H27 grinder (France) with 2-3 mm perforated plates. The ground mixture was combined with eggs, sprouted green buckwheat flour, salt, black pepper, and water, then homogenized in a ZB-8 mixer (China) until a uniform consistency was achieved. The resulting mixture was manually shaped into ten patties, each weighing 50 g with an approximate diameter of 8 cm and height of 1.5 cm. These were arranged on trays and frozen at –29 to –30°C for 1 h. Once frozen, the patties were vacuum-packed in 500 g portions (10 patties per pack), labeled, and stored at 4°C for further evaluations.

Table 1 – The formulation for control and test patties

Ingredients	Control	PEG5	PEG10	PEG15	PEG20
Horsemeat (grade I)	-	45	40	35	30
Beef 1 kat	75	-	-	-	-
Beef fat	7	-	-	-	-
Poultry meat	-	25	25	25	25
Horse fat	-	7	7	7	7
Germinated green buckwheat	-	5	10	15	20
Onion	5	5	5	5	5
White cabbage	-	5	5	5	5
Egg	5	5	5	5	5
Salt	1,1	1,1	1,1	1,1	1,1
Black pepper	0,2	0,2	0,2	0,2	0,2
Wheat flour (premium)	1,7	-	-	-	-
Germinated green buckwheat flour	-	1,7	1,7	1,7	1,7
Breadcrumbs (for coating)	5	-	-	-	-
Total	100	100	100	100	100

This product development initiative aligns with the evolving market demand for healthier, hybrid meat products. During formulation, special attention was given to balancing traditional sensory characteristics with modern consumer preferences – targeting individuals who seek to reduce meat intake without compromising on taste, texture, or convenience. The core ingredient of the patty is high-grade (Grade I) horsemeat, selected for its nutritional value and compatibility with plant-based components.

Organoleptic evaluation protocol

The quality of semi-finished meat products (cutlets) was evaluated based on organoleptic parameters, in accordance with the standards outlined in GOST 9959-2015. The organoleptic characteristics of the raw semi-finished products (cutlets) were determined by their appearance, including how they looked on the incision, their color (visually assessed through external inspection), and their odor. The finished products were analyzed after thermal processing in steam (at 100°C for 20 min), ensuring the internal temperature of the product reached 73°C. The appearance of the heat-treated products was examined, the type of minced meat was visually assessed in the section through external inspection, and the consistency was evaluated by pressing with fingers and chewing. Additionally, the smell (aroma) and taste were tested, including the intensity of the herbal supplement aroma and taste, as well as the presence or absence of any foreign odors, aftertaste, and lingering flavors. When developing the cutlet recipes, the taste and smell of the fully cooked products played a significant role. The results of the organoleptic evaluation were recorded using a dimensionless scale, expressed in points (a 5-point scale was employed in this study).

Microscopic Analysis of Cutlet Microstructure

To investigate the microstructural differences between control and vegetable-enriched meat patties, samples were prepared following standard histological protocols. Thin cross-sections of both

uncooked and cooked patties were taken and fixed in 10% neutral buffered formalin for 24 hours at room temperature. After fixation, the samples were dehydrated through a graded ethanol series, cleared in xylene, and embedded in paraffin. Sections of 5 μm thickness were cut using a microtome and mounted onto glass slides. For structural visualization, the sections were stained with hematoxylin and eosin (H&E), a standard protocol that allows for clear differentiation of cellular components. Stained slides were examined using a light microscope (Levenhuk MED D35T, USA) at various magnifications ($\times 50$ to $\times 1000$) under both low and medium power to observe fiber arrangement, connective tissue distribution, and the presence of plant-derived particles. Images were captured using a digital imaging system connected to the microscope. Micrographs were assessed for the presence and morphology of muscle fibers, connective tissue, fat cells, and plant cell components such as nuclei and cell walls. The comparative structural integrity and tissue integration between control and test samples were used to evaluate the impact of sprouted green buckwheat on the microstructure of the cutlets.

Results and Discussion

Antioxidant activity and Phenolic Profile of GGB Flour

The results of antioxidant activity and total phenolic content of non-germinated green buckwheat (NGGB) and germinated green buckwheat flours (GGBF) are presented in Table 2. The results obtained showed increased antioxidant activity and TPC in the germinated green buckwheat flour after seven days of germination. This can be explained by increasing hydrolytic enzyme activity due to the germination process [10]. The high level of polyphenolic components in buckwheat shows a high level of antioxidant activity of germinated green buckwheat. The content of the phenolic compounds after germination showed 3.97 mg/g, which is possibly due to the breakdown of the cell wall during germination.

Table 2 – Antioxidant and Phenolic Profile of NGGBF and GGBF

	Parameter	NGGBF	GGBF	p-Value
Antioxidant activity	TPC	200.35 $\pm$ 1.50	397.52 $\pm$ 1.50	**
	DPPH, %	63.25 $\pm$ 1.03	87.83 $\pm$ 1.03	**

*All values are mean $\pm$ standard deviation of triplicates. p-value: ** ($p < 0.01$), * ($p < 0.05$)*

Determination of organoleptic parameters of semi-finished meat products

The steamed cutlets had a juicy texture, with a typical meat product aroma. The taste was meaty and balanced, with a pleasant mild hint of vegetable additives. As the proportion of vegetable additives in the minced meat increased, the quality of the cutlets changed – the texture became less juicy, and the taste and smell developed a characteristic aftertaste, with a more pronounced aroma from the vegetable additives. The evaluation score for the semi-finished products (cutlets) after heat treatment is provided in Figure 2.

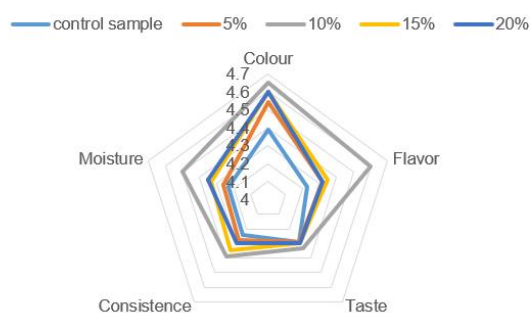


Figure 2 – Radar chart of organoleptic evaluation scores for meat-based semi-finished products with varying levels of sprouted green buckwheat flour substitution

Figure 2 illustrates the organoleptic evaluation of meat-based semi-finished products with varying levels of meat substitution using sprouted green buckwheat. The radar chart provides a comparative view of sensory attributes – colour, flavor, taste, consistency, and moisture – across five formulations. The patties with 10% substitution exhibited the most balanced and favorable profile, with consistently high scores in all categories, particularly in colour (4.65), flavor (4.6), and consistency (4.39). The 5% and 15% substitution levels also performed well, though the 20% substitution showed a slight decline in several parameters, suggesting possible sensory fatigue or

overpowering of plant-based notes. The control sample, while acceptable, demonstrated lower ratings across most attributes compared to the optimized formulations. This visual representation confirms that a 10% replacement level offers the best enhancement in overall sensory quality, indicating the optimal balance between traditional meat characteristics and the functional contribution of sprouted green buckwheat.

The presented organoleptic evaluation data show that the introduction of sprouted green buckwheat flour into the developed semi-finished products improves consistency, increasing the density, juiciness and softness of the product.

Microscopic analysis evaluation

The microstructure of meat patties without vegetable additives (control)

The microstructural evaluation of the control meat patties, which did not include vegetable additives, was conducted using light microscopy at varying magnifications. As illustrated in Figure 3A and 3B, the micrographs reveal well-preserved transverse and longitudinal muscle fibers, indicating minimal structural disruption during processing. Distinct connective tissue elements are visible, consisting of organized collagenous fibers and interspersed adipose cells. The boundaries between adjacent muscle fibers are clearly defined, and some fibers are seen fragmented into smaller segments, which is typical of mechanically processed meat. At medium magnification (Figure 3B), nuclei of muscle fibers and connective tissue cells remain intact and distinguishable, confirming the structural integrity of the muscle matrix. The absence of plant cell components further supports the control sample designation. These observations establish a microstructural baseline for evaluating the impact of sprouted green buckwheat incorporation in subsequent formulations, allowing for comparative assessment of tissue disruption, integration of non-meat components, and potential modifications in texture and consistency.

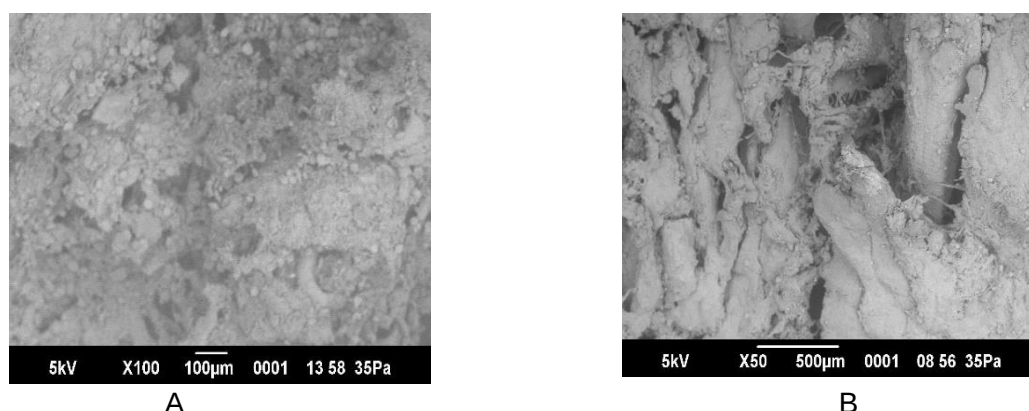


Figure 3 – Microstructure of meat patties without vegetable additives:
(A) transverse view at $\times 100$ magnification; (B) longitudinal view at $\times 50$ magnification

The microstructure of meat patties with vegetable additives (test).

The microstructural examination of meat patties formulated with sprouted green buckwheat revealed distinct morphological features compared to the control. As depicted in Figure 4A and 4B, the transverse and longitudinal muscle fiber bundles exhibit expanded inter-fiber gaps, likely due to water displacement from the freezing and fixation process. Embedded within the meat matrix, numerous plant-derived structures are evident, including both large and small granules of sprouted green buckwheat powder and distinguishable plant cell nuclei. These plant nuclei are notably larger and more spherical in shape than the elliptical nuclei of animal muscle or connective tissue cells, allowing for unambiguous identification of plant inclusions. The connective tissue framework remains visible, though more diffusely distributed, and appears to accommodate the heterogeneous integration of vegetal material. The overall tissue organization is less compact, reflecting a looser association among muscle fibers and added plant particles. These microstructural patterns suggest that the incorporation of sprouted green buckwheat introduces significant physical heterogeneity, which may influence the texture, water retention, and overall consistency of the final product.

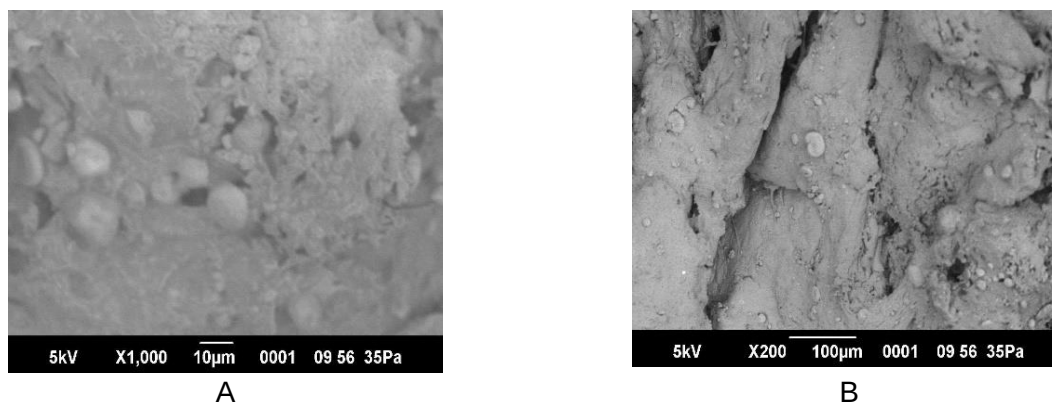


Figure 4 – Microstructure of meat patties with vegetable additives:

(A) magnified view at $\times 1000$ showing plant cell nuclei and particulate matter;

(B) general matrix view at $\times 200$ illustrating tissue integration and distribution of sprouted buckwheat particles.

Conclusions

The incorporation of sprouted green buckwheat (SGB) into meat-based semi-finished products presents a promising strategy for enhancing nutritional quality and functional performance without compromising consumer acceptability. This study demonstrated that replacing up to 15% of meat content with sprouted green buckwheat and its flour improves key organoleptic properties such as juiciness, texture, and overall flavor, with 10% substitution offering the most favorable balance across all sensory attributes. Microstructural analysis confirmed the successful integration of plant-based components within the meat matrix, revealing distinct yet cohesive distribution of sprouted buckwheat particles among muscle fibers. Additionally, the antioxidant activity and total phenolic content of germinated green buckwheat flour significantly exceeded those of its non-germinated counterpart, supporting its role as a functional bioactive ingredient. These findings validate the technological feasibility of using SGB in the development of hybrid meat products and highlight its potential in creating health-oriented, sustainable alternatives aligned with modern dietary trends. Further studies may explore the impact of such formulations on shelf life, consumer perception, and large-scale processing stability.

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ӨНГЕН ЖАСЫЛ ҚАРАҚҰМЫҚТЫҢ ЖАСАЛҒАН ЕТ КОТЛЕТТЕРІНІҢ ОРГАНОЛЕПТИКАЛЫҚ ҚАСИЕТТЕРІ МЕН МИКРОҚҰРЫЛЫМЫНА ӘСЕРІ

Бұл жұмыста өнген жасыл қарақұмықтың (ӨЖҚ) еттен жасалған жартылай фабрикаттардың (котлеттердің) сапалық көрсеткіштеріне әсері қарастырылады. Негізгі мақсат – ӨЖҚ-ты дәстүрлі рецептураларға қосу арқылы органолептикалық және құрылымдық қасиеттерді жақсартудың орындылығын бағалау. Ет қоспалары жылқы еті мен құс етін 5%, 10%, 15% және 20% мөлшерде ӨЖҚ-пен ішінара алмастыру арқылы дайындалды. Органолептикалық қасиеттері – түсі, дәмі, консистенциясы, иісі мен шырындылығы – 5 балдық шкала бойынша бағаланды. Сонымен қатар, өсімдік компонентінің ет құрылымына таралуы мен кірігуін бақылау үшін микроструктуралық талдау жүргізілді. Нәтижелер көрсеткендей, 15%-ға дейінгі алмастыру котлеттердің текстурасы мен шырындылығын жақсартты, ал 20% алмастыру сенсорлық сапаға теріс әсер етті. Микроскопиялық бейнелер ӨЖҚ қосылғанда құрылымдық біркелкіліктің артқанын көрсетті. Алынған деректер өнген жасыл қарақұмықты ет котлеттерінің текстурасы мен тұтынушылық сапасын төмендетпей жақсартуға арналған функционалды өсімдік қоспасы ретінде қолдану мүмкіндігін растайды. Бұл зерттеу калориясы төмен, пайдалы, құрамында теңгерімді және функционалды қасиеттері бар жартылай фабрикаттарды жасауға ықпал етеді.

Түйін сөздер: жасыл қарақұмық, жылқы еті, құс еті, ет қоспалары, қоректік заттарға бай котлеттер, сапалы өнім.

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ВЛИЯНИЕ ПРОРОЩЕЙ ЗЕЛЕННОЙ ГРЕЧКИ НА ОРГАНОЛЕПТИЧЕСКИЕ СВОЙСТВА И МИКРОСТРУКТУРУ МЯСНЫХ КОТЛЕТ

В данной работе рассматривается влияние пророщенной зелёной гречки (ПЗГ) на качественные показатели мясных полуфабрикатов (котлет). Основной целью было оценить целесообразность добавления ПЗГ в традиционные рецептуры для улучшения органолептических и структурных свойств. Мясные смеси были приготовлены, путем частичной замены конины и мяса птицы на ПЗГ в пропорциях 5%, 10%, 15% и 20%. Органолептические свойства, включая цвет, вкус, консистенцию, аромат и сочность, оценивали по 5-балльной шкале. Также проводился микроструктурный анализ для наблюдения за распределением и встраиванием растительного компонента в мясную матрицу. Результаты показали, что замена до 15% улучшила текстуру и сочность котлет, тогда как 20% – отрицательно повлияла на сенсорное качество. Микроскопические изображения показали улучшение структурной однородности при введении ПЗГ. Полученные данные подтверждают потенциал использования пророщенной зелёной гречки в

качестве функционального растительного ингредиента для улучшения текстуры и потребительских качеств мясных котлет без ущерба для качества. Это исследование способствует разработке низкокалорийных, полезных полуфабрикатов, со сбалансированным составом и функциональными свойствами.

Ключевые слова: зеленая гречка, конина, мясо птицы, мясные смеси, котлеты, богатые питательными веществами, качественный продукт.

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